



**Army Open System Demonstration (AMCOM)  
Open Systems Project Engineering Conference (OSPEC)  
FY 98 Status Review  
29 April - 1 May 1998**

**Bruce Lewis**  
**US Army Aviation and Missile Command**  
**Steve Vestal**  
**Honeywell, Principal Investigator**

# Agenda

---



- **Project Description**
- **Goals**
- **Requirements**
- **Tasks/Technical Approach**
- **Results/Recommendations**
- **FY 98 Tasks/Schedule**

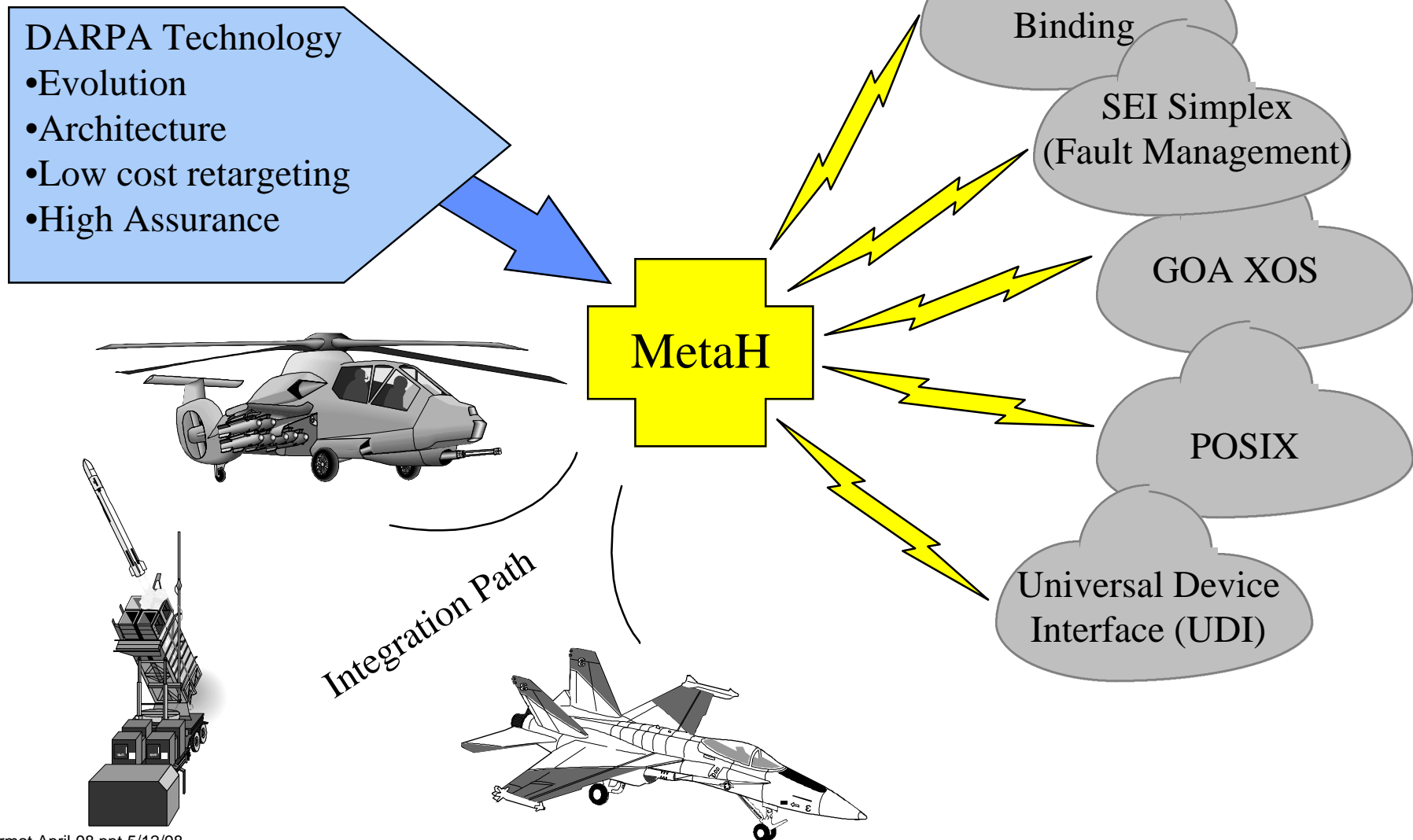
## **What Changes Are Needed to POSIX to Satisfy Missile and Aviation System Requirements? How Can We Know?**

---

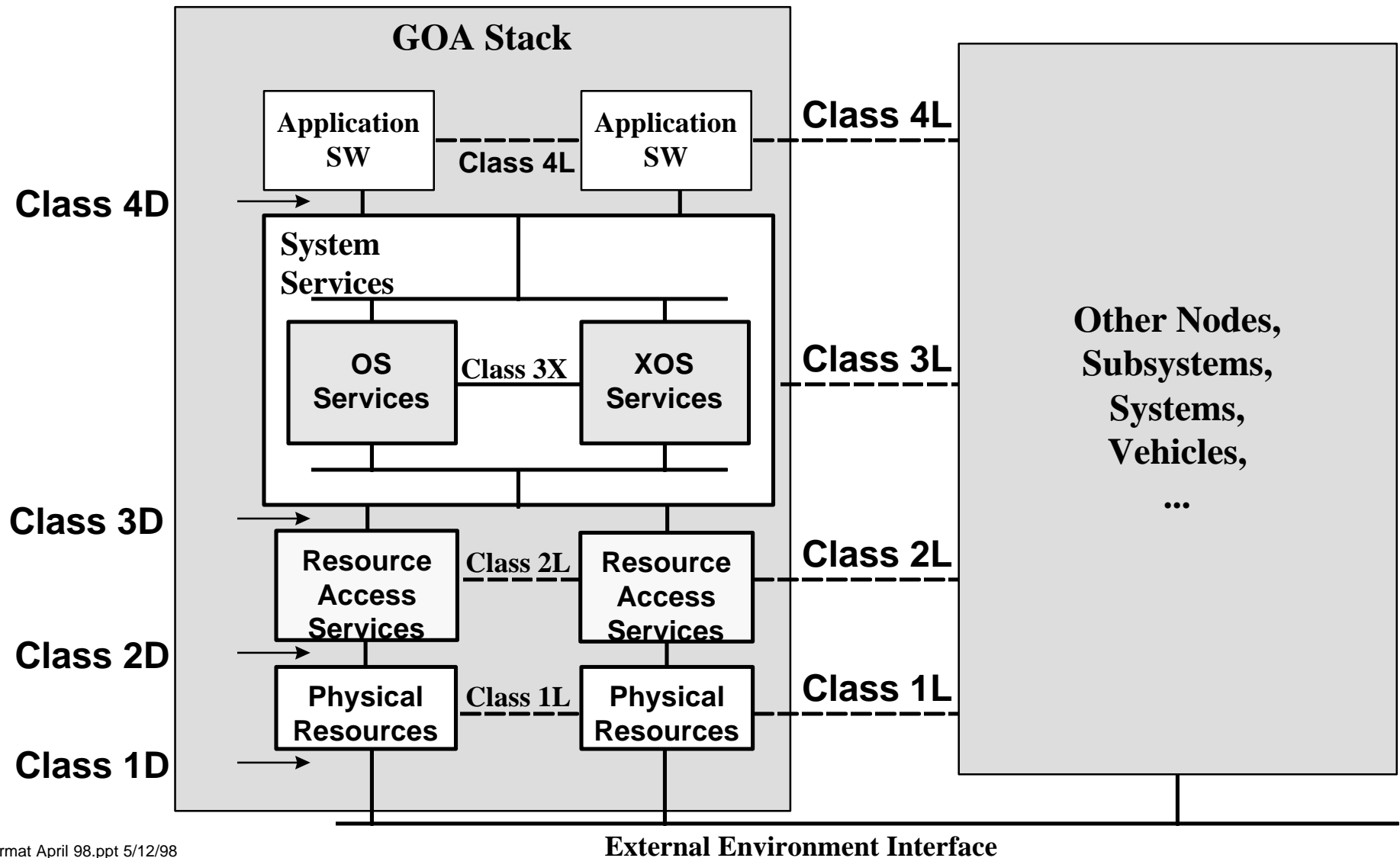


- **Test Many Different Systems by Implementing Them on Top of POSIX.**
  - Expensive!
  - Takes too long! ..... or
- **Implement MetaH on Top of POSIX.**
  - MetaH satisfies a broad range of current and anticipated missile and aviation systems.
  - Cost is reasonable.
  - Will provide quantitative results for
    - performance.
    - adequacy of current POSIX features with recommendations for enhancements and/or new features.
  - Leverages POSIX into DARPA rapid development environment.

# Synergism and Integration Path

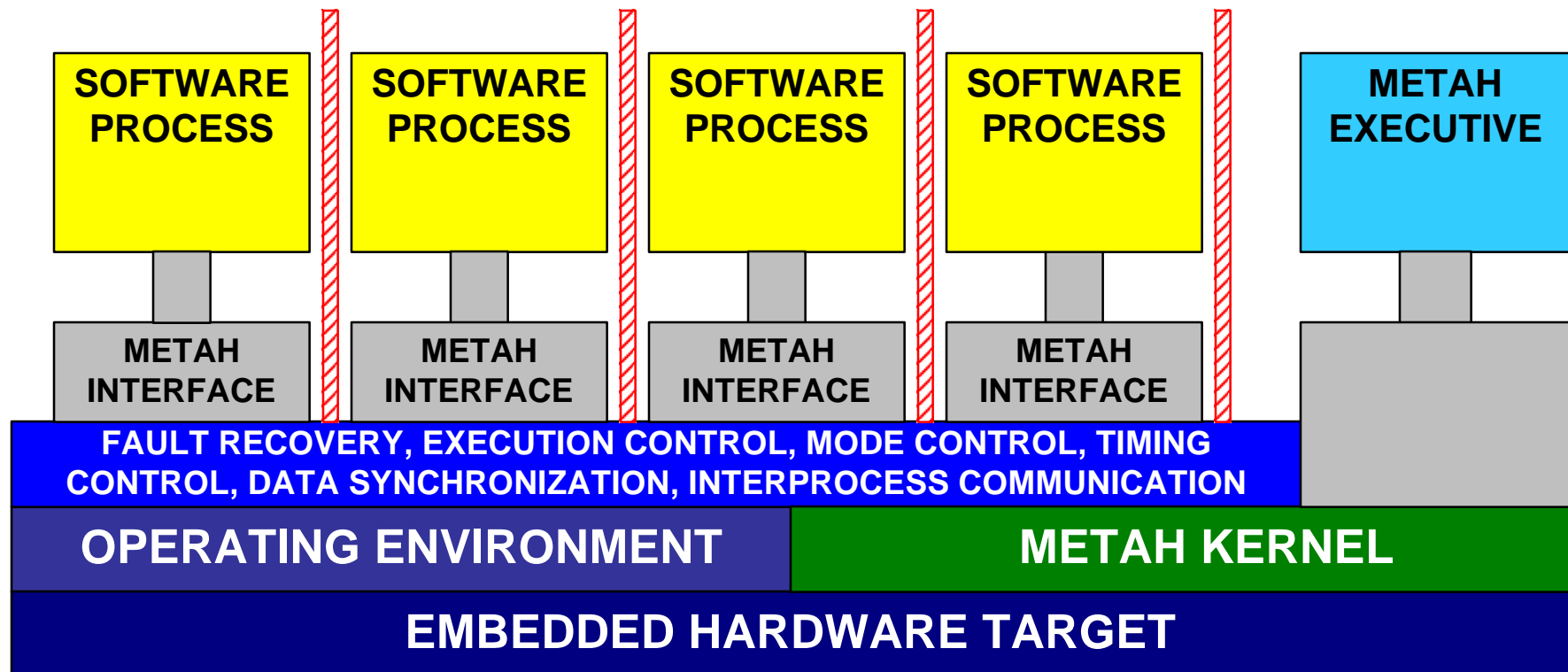


# Society of Automotive Engineers Generic Open Architecture Stack





- Strong Partitioning - Not Just Memory Protection But Also ...
  - Timing Control
  - Process Control
  - Interface Control





- **Discover missing required capabilities for Avionics**
- **Reduce adoption barriers for MetaH and SAE/POSIX by working with programs, vendors to meet requirements**
- **Reflect advanced Avionics requirements into SAE/POSIX standards**
- **Demonstrate usability**
- **Leverage POSIX and related Standards into advanced DARPA Developments**
- **Start standardization of MetaH Architecture Description Language for Avionics**



## Objectives

- Assess benefits of achievable portability using real-time POSIX
- Assess suitability of real-time POSIX for MetaH-produced missile and helicopter avionics software
- Identify possible POSIX and MetaH enhancements

## Methodology / Tasks

- Survey POSIX documents and vendors
- Survey missile and helicopter program requirements
- Prototype a MetaH retarget to a real-time POSIX implementation

# Missile and Helicopter Requirements

---



- **Functional**
- **Processor time and space**
- **Development process**

# Missile and Helicopter Functional Requirements

---



- **Some functional requirements are outside POSIX and MetaH scope**
  - Initial hardware self-test
  - Memory management, e.g. ROM-to-RAM code copies
  - Low-level error management, e.g. lock-step pair restart
  - Hardware device interfaces
  
- **Missile and helicopter functional requirements were largely inferred from MetaH requirements**
  - MetaH is emerging technology
  - Incorporates methods widely-used in practice
  - Incorporates methods that anticipate future systems

# Missile and Helicopter Time and Space Requirements

---



## Some data obtained from

- OH-58D helicopter (Kiowa Warrior)
- Patriot Anti-Cruise missile (PACM)
- Theatre High-Altitude Air Defense (THAAD)
- Army Tactical Missile System (Army TACMS)
- Inertial Flight Measurement Unit (Honeywell IFMU)

## Missile Profile

**Multi-processor**

**Some Heterogeneous DSP+GPP**

**1MB memory/processor**

**500Hz high rate**

## Helicopter Profile

**Multi-processor**

**Heterogeneous DSP/GPP**

**10MB memory/processor**

**50 Hz high rate**

**Some security**

# Missile and Helicopter Development Process Requirements

---

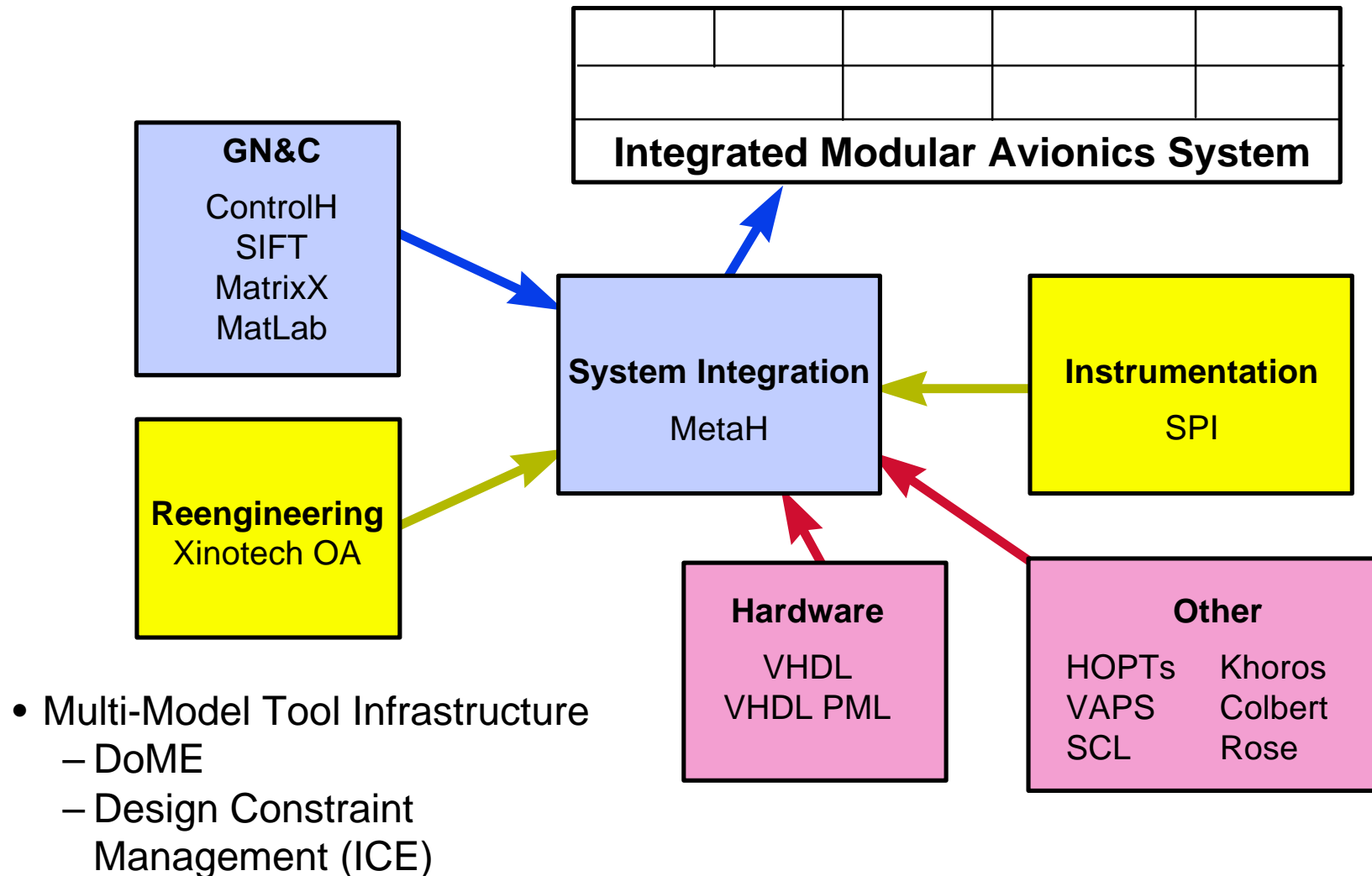


- **Verification**

- RTOS must be verified, too
- Partitioning

- **Multi-Platform Development**

- Workstation    testbed    flight system





## Not a traditional CASE tool

**specialized for hard real-time, fault-tolerant, safely/securely partitioned, scalable multi-processor systems**

**integration toolset with open interfaces to domain-specific generators, re-engineering tools, module libraries, etc.**

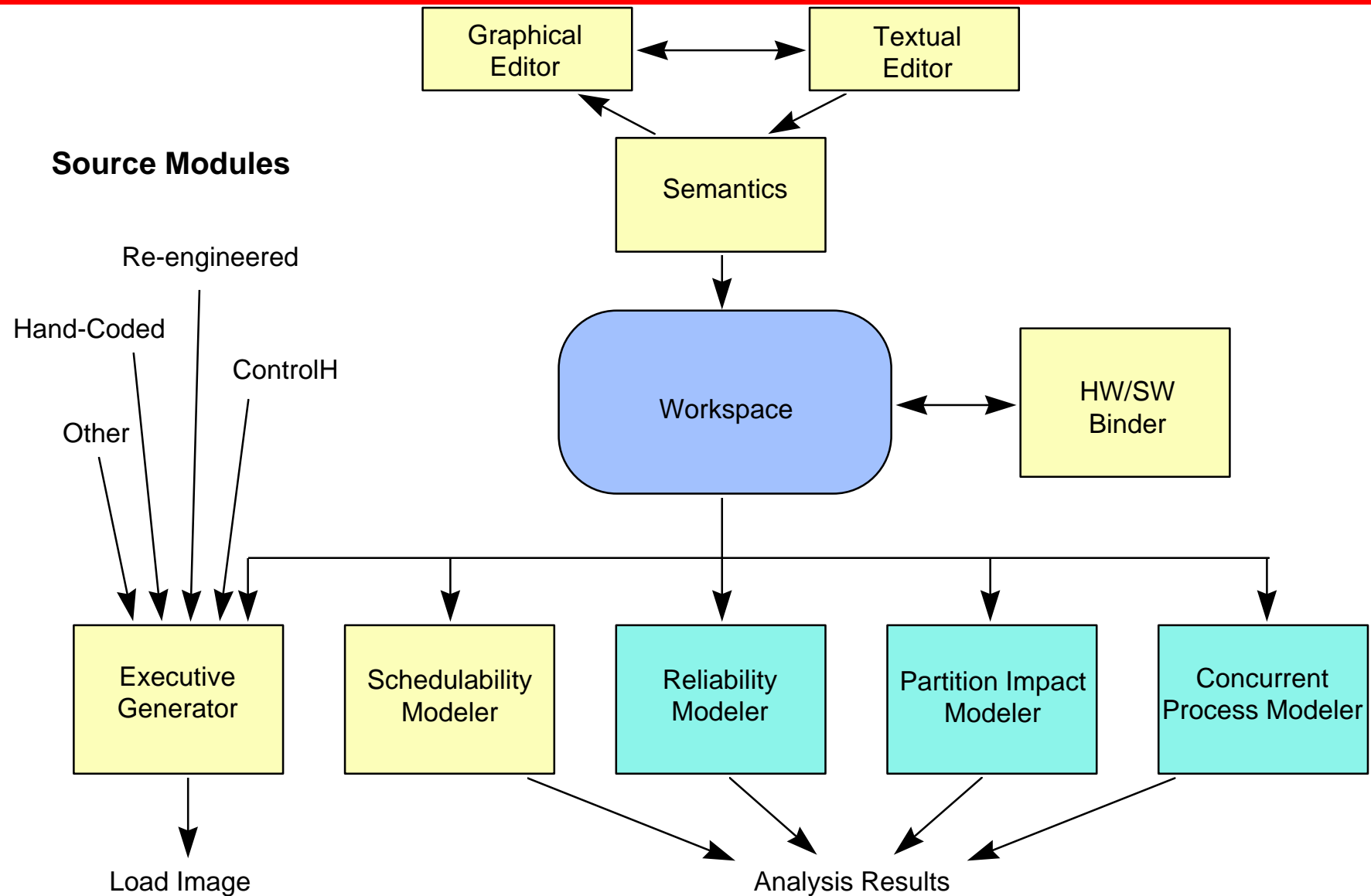
**closely couples formal modeling and analysis with design and implementation**

**attentive to software/hardware interface, multi-processor systems, software/hardware configurability and protability**

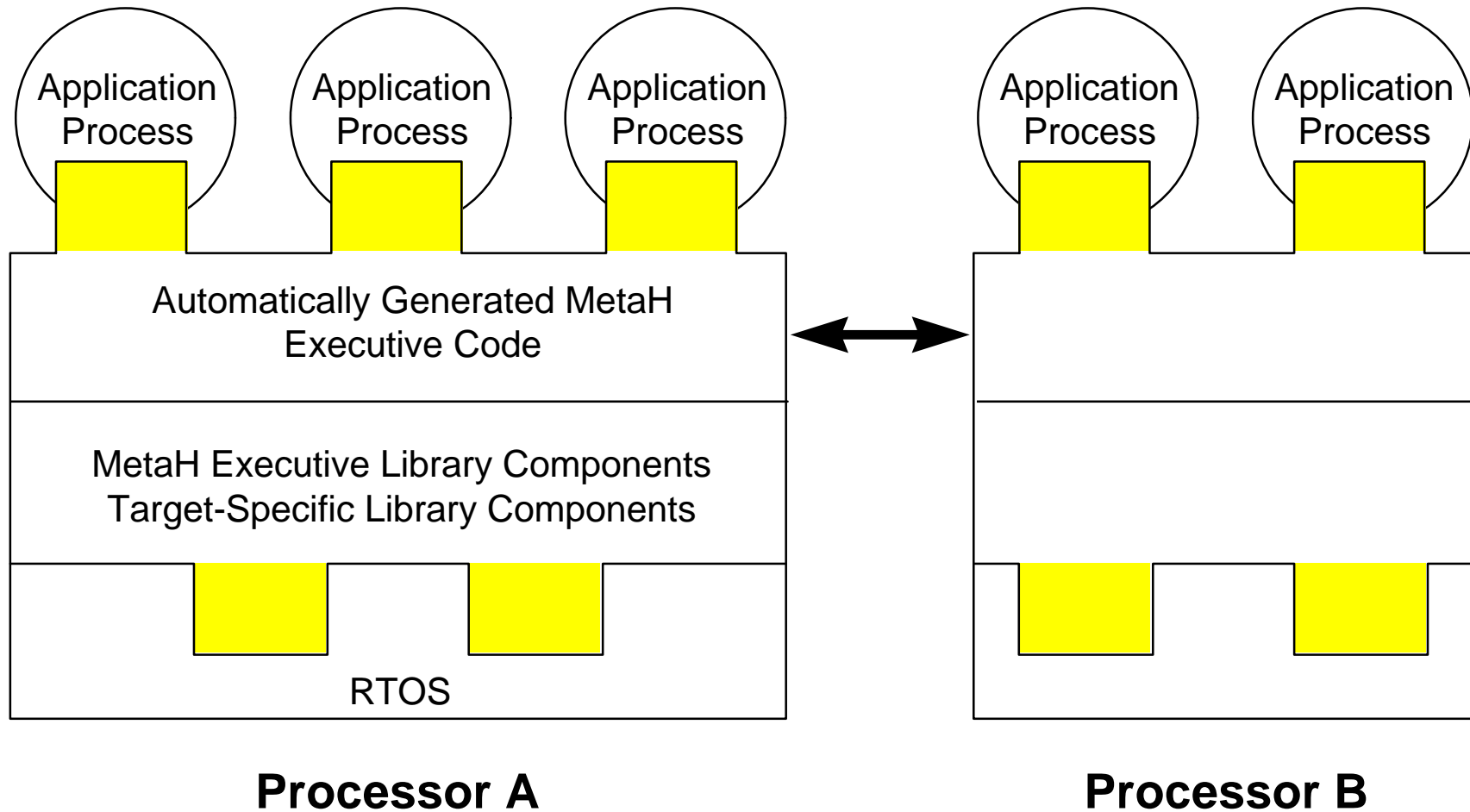
## Not a traditional Real-time Operating System

**designed to be retargeted to desired execution environment, including existing real-time run-times/kernels/operating systems**

**application-specific executive is tailored for each application, off-line configuration enables faster and smaller executives**



# MetaH Executive “Glue” Code





# Prototype Technical Approach

---

- **Design Decisions**
  - Where does MetaH glue code/function go?
  - How do processes communicate with MetaH executive?
  - How is the MetaH process life cycle managed?
  - How are MetaH shared objects implemented?
  - How is MetaH message passing implemented?
  - How is synchronization supported?
  
- **Alternatives and Selections**
  - Try to support full MetaH
  - Try to use simplest, most direct choices

# Summary of Effort

---



- **POSIX documents and tools reviewed, tools selected**
- **Prototype based on POSIX was partially functional**
- **Much of the prototyping effort was spent filling POSIX gaps and bugs (we filled in vendor's gaps using FSU Florist)**
- **About 70 objects from 11 POSIX packages referenced**
- **Recommendations presented to SAE and POSIX**



# Portability Conclusions

---

- **Portability is limited by incomplete implementations**
- **There are situations where significant benefits are possible anyway**
  - **Proven architecture concepts**
  - **Some source portability**
  - **Portability from workstation to testbed to flight hardware**
  - **Ease processor upgrades**
- **Allocate your own resources to insure an appropriate implementation**



- **Neither current POSIX standards or commercially available implementations are likely to support fully partitioned MetaH off-the-shelf**
- **Partially partitioned MetaH on a reduced vendor-specific POSIX profile is possible and would meet requirements of many helicopter systems**
- **Unpartitioned MetaH with restricted aperiodic scheduling on a reduced vendor-specific POSIX profile or on Ada95 is possible and would meet requirements of many missile systems**



## **Desired POSIX enhancements**

- **Support for adaptive real-time scheduling**
- **Support for partitioning**
- **Support for extended executives**

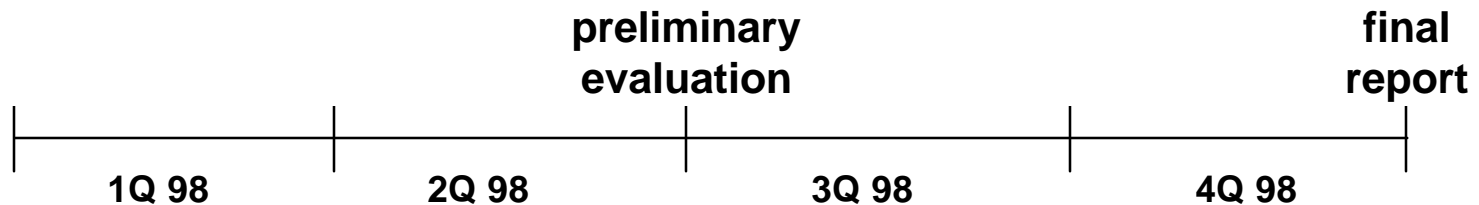
## **Desired MetaH enhancements**

- **Subsets for minimal RTOS configurations**
- **Improved event processing**
- **Standard IO and device interfaces**



# 1998 Plans

- **Begin Metah standardization process**
- **Preliminary evaluation of the following activities, followed by selection and focus on one**
  - **Extend work on POSIX, MetaH and LynxOS to support and demo efficient fully partitioned and adaptively scheduled multi-processor systems**
  - **Prototype POSIX, MetaH and pAOS to support and demo efficient fully partitioned and adaptively scheduled multi-processor systems**
  - **Incorporate a UDI interface capability in MetaH and experiment with available devices and drivers.**





# Additional Information

# MetaH Scheduling and Allocation Features

---



- Periodic and aperiodic processes
- Preperiod deadlines and communication
- Process criticalities
- Multiple user-selectable real-time semaphore protocols
- Hard real-time multi-processor port-to-port communication
- Dynamic reconfiguration of processes and connections
- Processor and channel real-time schedulability analysis
- *Constraint specifications for software/hardware binding*
- *Process chaining for undelayed messages and ordering*
- *Slack scheduling of aperiodic, incremental, queue server processes*
- *Multiple subtasks within multiple threads*



# MetaH Partitioning Features

---

- Processes are allocated individual protected address spaces
- Execution time limits can be specified and enforced
  - Elaboration time
  - Initialization time
  - Compute time
  - Semaphore locking time
- Process scheduling criticalities can be specified
- Process only has the run-time capabilities granted in the specification
- *Communication, data access and scheduling interference checked against specified safety/certification level and data rights attributes*



# MetaH Fault-Tolerance Features

---

- Default behaviors for unhandled application process exceptions
- Process time limits and criticalities to handle timing faults
- Communication and semaphore protocols detect and report faults
- Plug-replaceable inter-processor executive consensus protocol
- *Error models and fault attributes allow specification and reliability modeling of redundancy management architectures*
- *Dynamic reconfiguration (mode changes) with processor restart*
- *Event consensus expressions for fault-tolerant mode changes*



- Retargetable to selected language toolset and RTOS
- Software/hardware interface features: hardware ports, hardware monitors, hardware events
- Processor and device specifications identify driver and interface source modules
- Channel specification used to connect processors in arbitrary topologies
- *Decrease retargeting effort through standard interfaces: Ada95, POSIX, UDI, . . .*
- *Extend distributed scheduling to handle low-bandwidth, high-latency channels, e.g. 1553, CAN, ARINC 659, . . .*

# Where does MetaH Glue Code/Function Go?

---

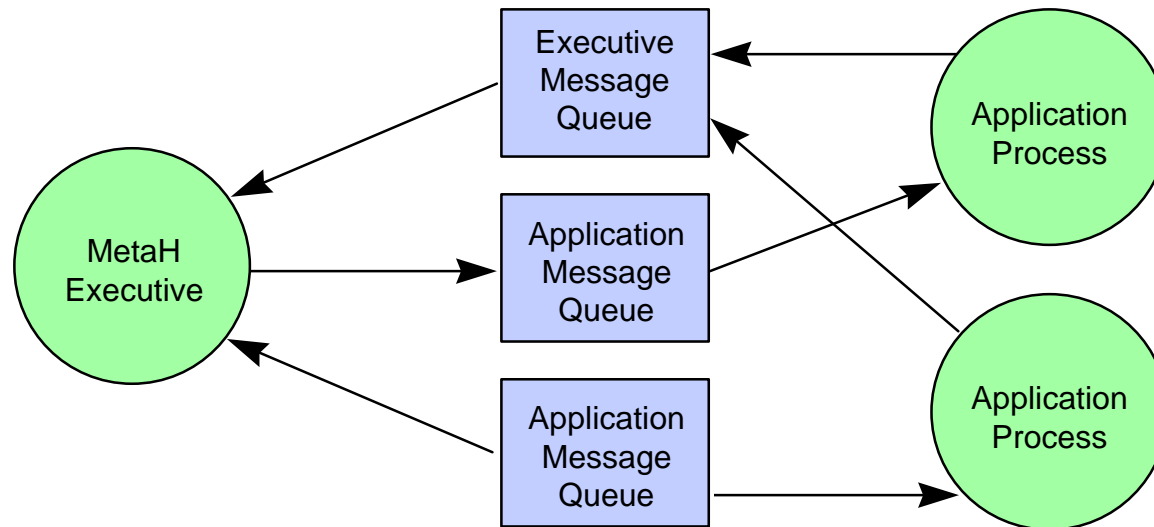


- Map all MetaH services to POSIX services
- Include executive code in application processes
- Add executive code to RTOS kernel
- **Executive code in a separate POSIX process**

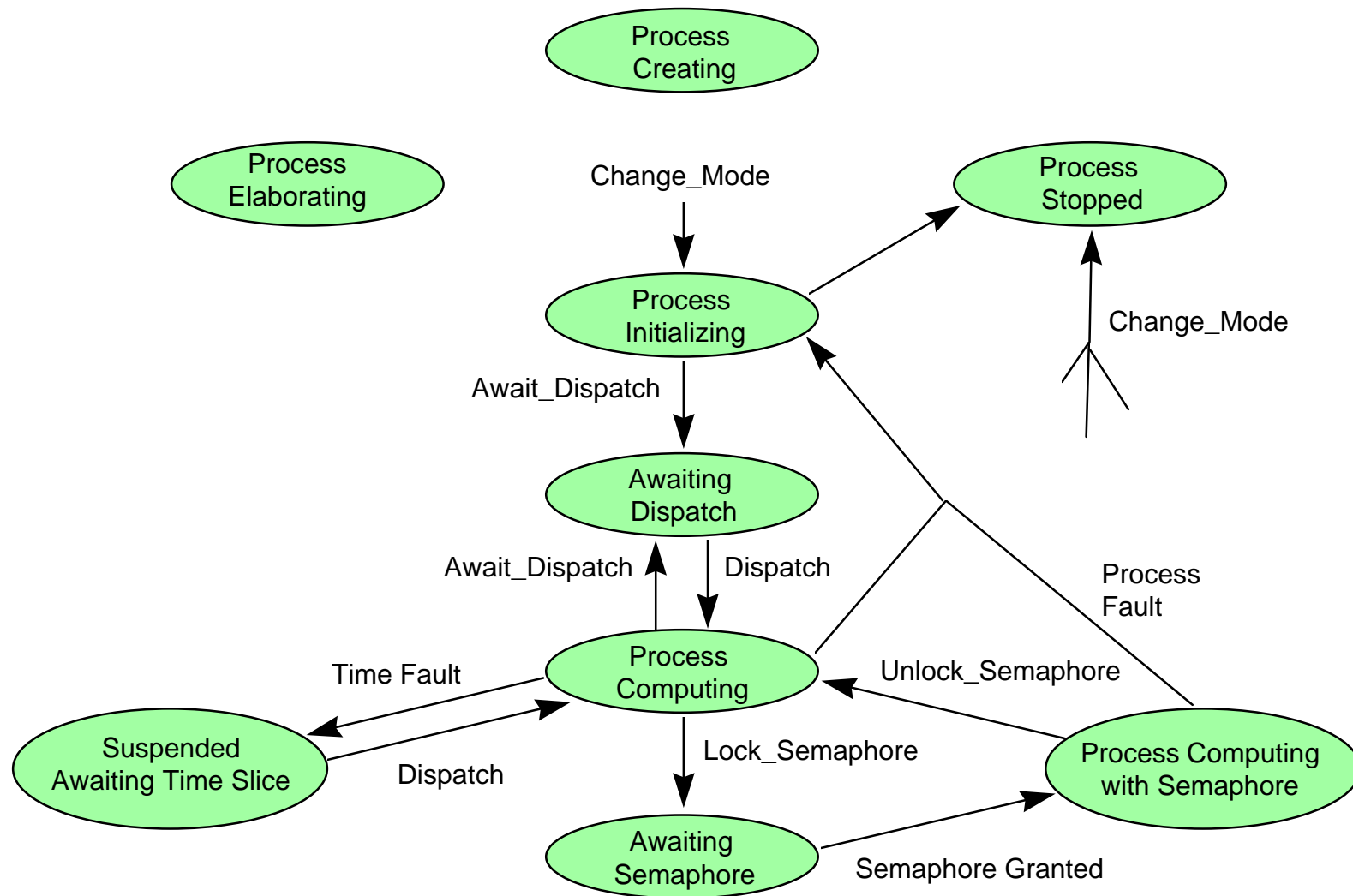
# How do Processes Communicate with the MetaH Executive?



- Traps, inter-address-space procedure calls
- Shared memory for parameters and results
- **Messages for parameters and results**
- Semaphores for call/return synchronization
- **Signals for call/return synchronization**



# MetaH Process Life Cycle



# How is the MetaH Process Life Cycle Managed?

---



- Process restart service
- **Process start and terminate service**
- Generate “wrapper” for each process

# How are MetaH Shared Objects Implemented?

---

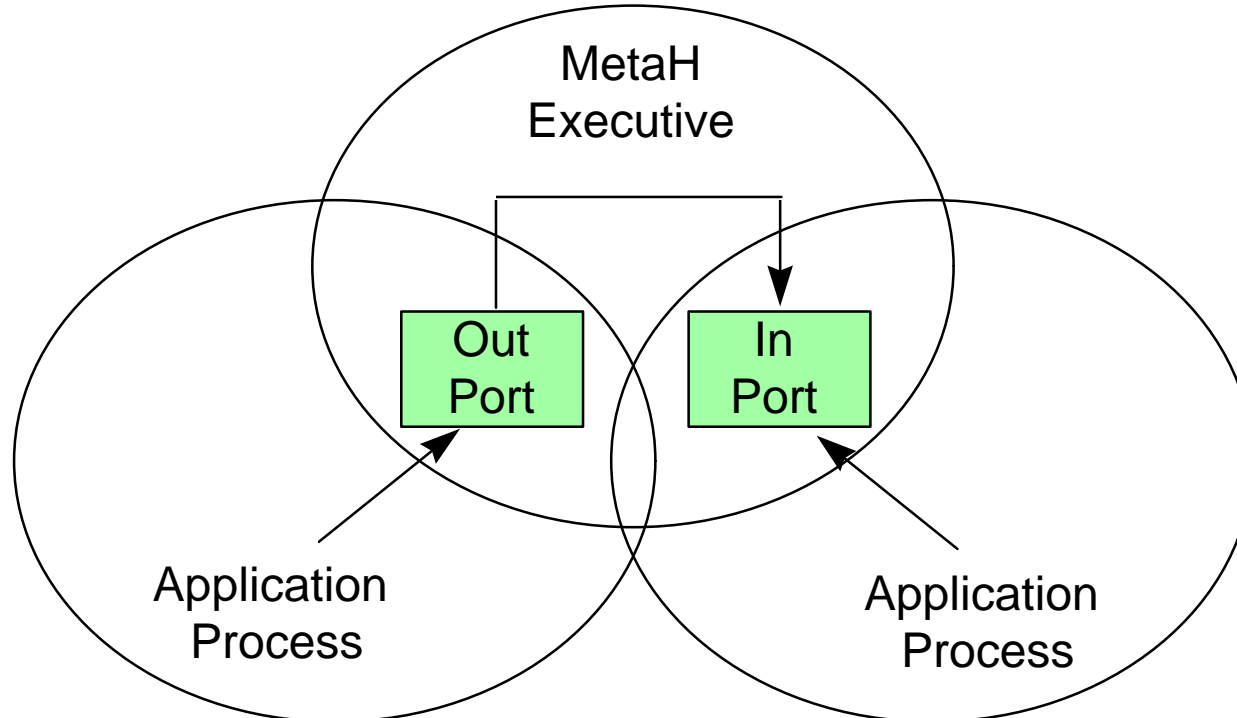


- Linker overlays
- Ada95 shared passive packages
- Shared memory objects and generated address clauses

# How are MetaH Messages Implemented?



- POSIX message services
- **Assignments through shared memory objects**



# How is Synchronization Supported?

---



- Applications directly use POSIX services
- **MetaH semaphores built using POSIX services**



# Summary of Effort

---

- Total evaluation (including surveys and paperwork) about 4MM
- Partially functional prototype produced
  - Preprocessing, compile, link by hand
  - Ran some simple examples
  - Several features unimplemented
- Code referenced about 70 objects from 11 POSIX packages

POSIX

POSIX\_IO

POSIX\_MEMORY\_LOCKING

POSIX\_MEMORY\_MAPPING

POSIX\_MESSAGE\_QUEUES

POSIX\_PERMISSIONS

POSIX\_PROCESS\_IDENTIFICATION

POSIX\_PROCESS\_PRIMITIVES

POSIX\_PROCESS\_SCHEDULING

POSIX\_SHARED\_MEMORY\_OBJECTS

POSIX\_SIGNALS

# Our Portability Experiences

---



- **Commercial products offer a subset of what we wanted**
- **We filled in gaps using Florist from FSU**
- **We spent a lot of time on POSIX interface implementation**



# Portability Benefits

---

- **Common and proven architecture and design concepts**
- **Some source code portability**
- **Portability is always limited by application dependence**
- **Process portability: workstation      testbed      flight system**
- **Ease processor upgrades to reduce recurring hardware cost**



# Possible POSIX Enhancements

---

- **Control child priority at start**
- **Control child process thread priorities**
- **Child process restart (running and terminated)**
- **Execution time monitoring, limiting, stop/continue**
- **Restrict child calls that impact scheduling, memory allocation**
- **Semaphore semantics to handle fault while locked**
- **Rapid parent/child service request (e.g. passive parent)**



# Possible MetaH Enhancements

---

- **Additional Semaphore Capabilities**
  - Conditional variables
  - Mutexes
- **Unpartitioned MetaH**
  - Identical defect-free semantics
  - Identical RTOS interface, or at least identical MetaH- generated code
- **Simplified aperiodic protocols**
- **Additional event selection & queueing features**



## Other Documents and Standards

---

- **Proposed POSIX additional realtime extensions**
- **Proposed POSIX application environment profiles**
- **Proposed realtime distributed communications**
- **SAE Generic Open Architecture (GOA) framework**
- **Uniform Driver Interface (UDI)**
- **Intelligent Input/Output (I<sub>2</sub>O)**

# Draft POSIX Additional Realtime Extensions

---



- **MetaH designed to easily add selectable semaphore protocols, can pass reader/writer and spin-lock capabilities on to application processes. Multi-processor protocols in particular offer complex trade-offs**
- **Interface to shared storage pools across multiple processors should be as compatible as possible with shared memory object interface, e.g. shared memory objects come from local storage pool**
- **MetaH needs system-wide periodic signal driveable from synchronized system clock**

# Draft POSIX Application Environment Profiles

---



- **Minimal Realtime System Profile is a reasonable baseline for flight systems**
- **Desire process interfaces for upward compatibility, with suitably limited semantics**
- **Full processes with protected address spaces and time partitioning would be suitable for IMA systems**



- **MetaH would create endpoints and connections between executives on different processors at start-up**
- **Would like to send different object types (or at least subtypes) over connections**
- **Directory services shouldn't be essential for this**
- **Buffer management, configuration, and heterogeneous systems support useful (heterogeneous languages, too)**
- **MetaH requires a communications schedulability model**
- **MetaH manages end-to-end system scheduling and analysis, interface to a communications link is by timing message release and requiring a delivery deadline**
- **Priority is not directly meaningful for many types of communications link hardware**

# SAE Generic Open Architecture Framework

---



- **MetaH executive is an eXtended Operating System (XOS)**

# Uniform Driver Interface Intelligent Input/Output

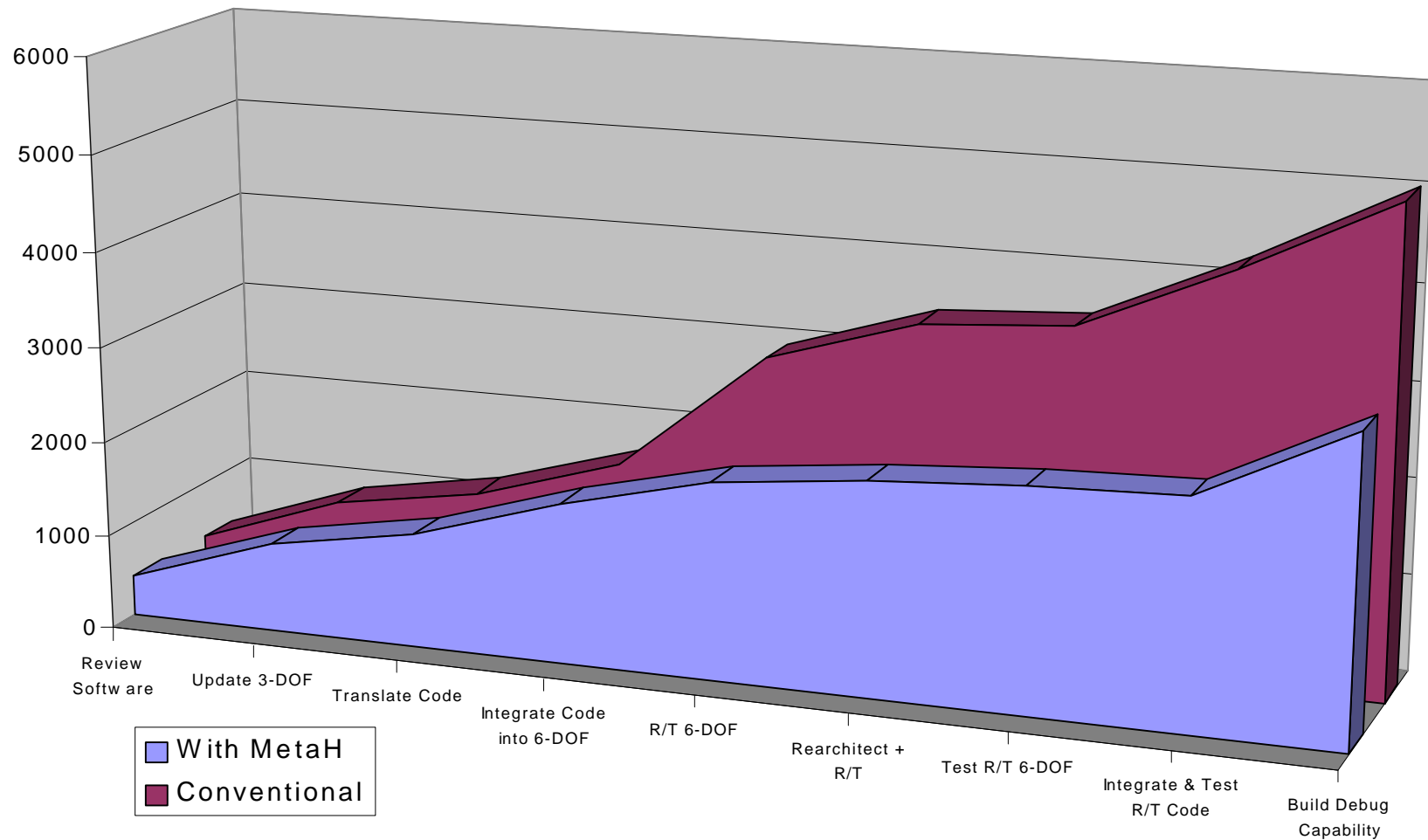
---



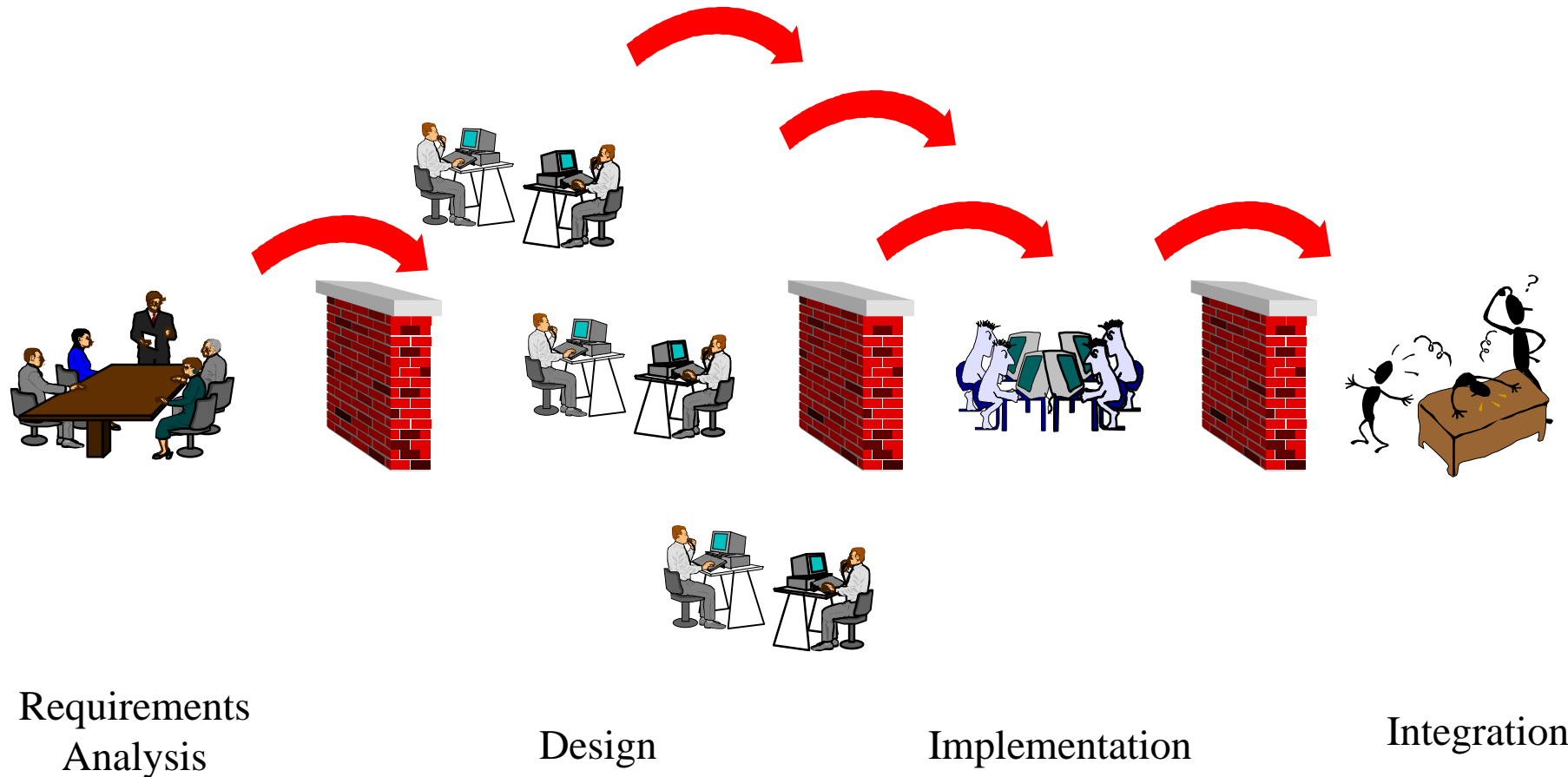
- **POSIX provides interfaces only for some classes of devices, e.g. mass storage, terminals**
- **MetaH would treat UDI modules like others that are being selected and composed into an application, but would need to support a UDI environment for them**
- **Some avionics system components are best treated as MetaH devices (IOPs) rather than MetaH processors, e.g. smart sensors, smart-head displays. Integration with an I<sub>2</sub>O toolset/environment might be appropriate**

# Effort Saved Using MetaH

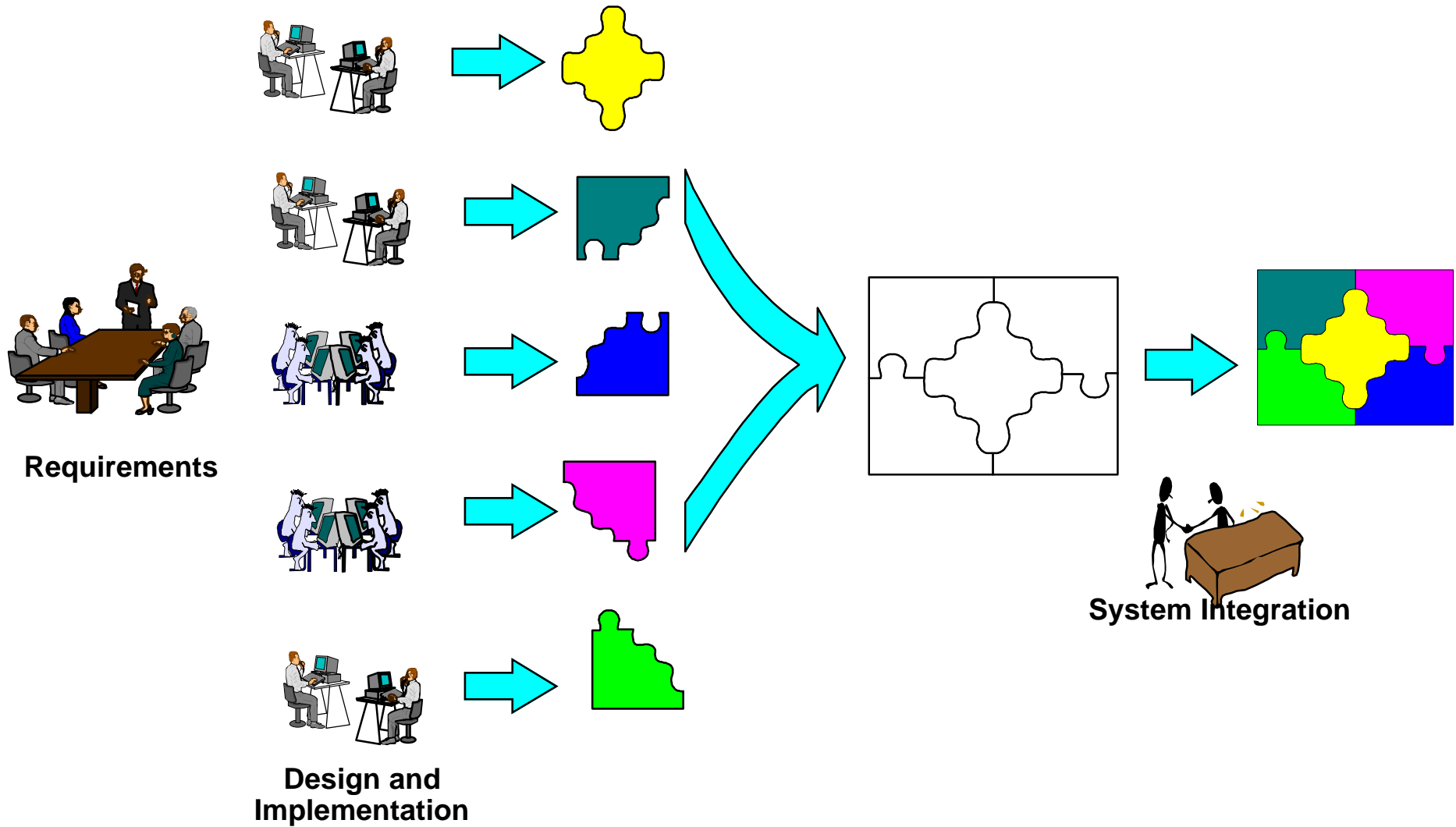
Estimated 37% reduction in Total Effort



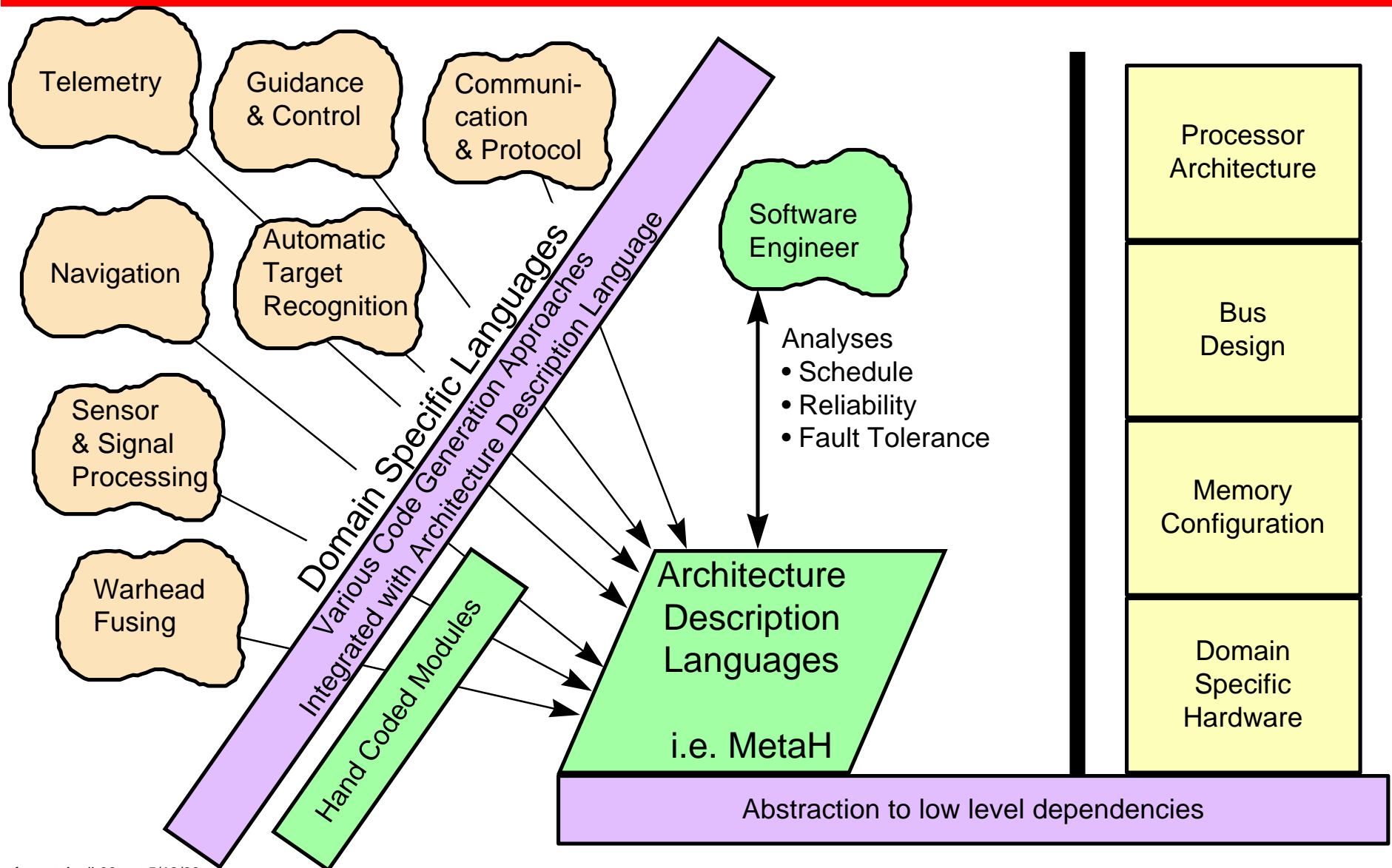
# Complex Systems Engineering: A Multi-Disciplinary Engineering Process!



# Architecture: The Missing Link in Engineering!



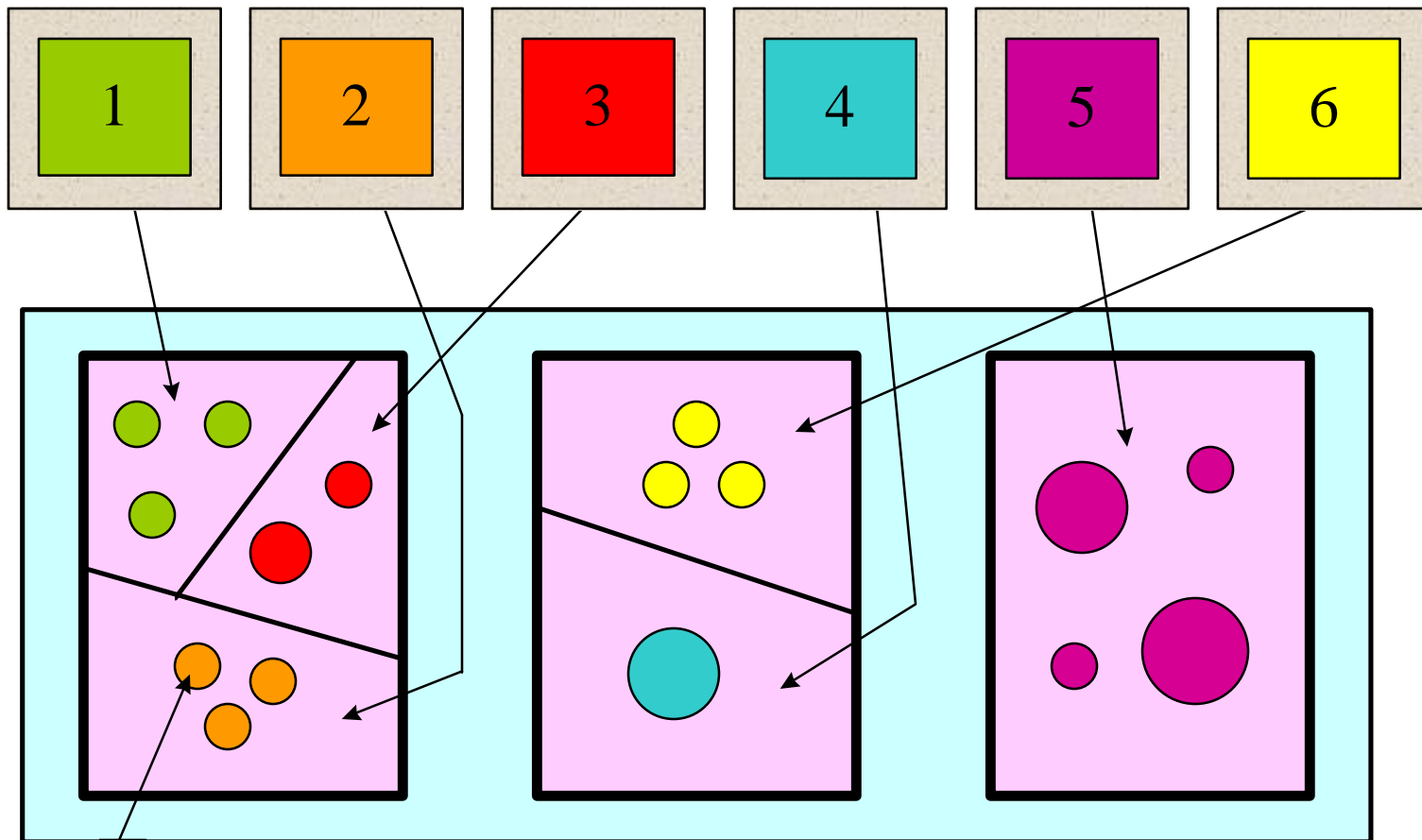
# Paradigm for Architecture Based Software Development



# Mapping to a Modular System



- Individual Units Map to Different Areas of Modular System's Resources



Partitions Needed to Separate Individual Components Within a Resource